



Langley Research Center

LPR 1740.5

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**PROCEDURES FOR CLEANING OF SYSTEMS AND EQUIPMENT
FOR OXYGEN SERVICE**

National Aeronautics and Space Administration

RESPONSIBLE OFFICE: OFFICE OF SAFETY AND MISSION ASSURANCE

PREFACE

This Langley Research Center Procedural Requirements (LPR), included in the Langley Research Center (LaRC) Facility Assurance Manual, establishes the cleanliness levels, cleaning, protection, and inspection for surfaces of parts, components, assemblies, subsystems, systems, or other related equipment in contact with oxygen service media. This procedure is to be used in cleaning equipment for oxygen service and is applicable to other services requiring a similar degree of cleanliness. This LPR defines LaRC's program to meet the requirements of NSS 1740.15, "NASA Standard for Oxygen and Oxygen Systems."

LAPG 1740.5, dated October 5, 2000, is rescinded and should be destroyed.

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Deputy Director

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Chapter 1**1. INTRODUCTION****1.1. PURPOSE**

This Langley Research Center (LaRC) Procedural Requirements (LPR) establishes the cleanliness levels, cleaning, protection, and inspection for surfaces of parts, components, assemblies, subsystems, systems, or other related equipment in contact with oxygen service media.

This procedure shall be used in cleaning equipment for oxygen service and is applicable to other services requiring a similar degree of cleanliness.

1.2. GENERAL

Precautions to be taken in the selection of materials will vary with the type of oxygen service encountered. Types of oxygen service include:

- Liquid oxygen.
- High-pressure gaseous oxygen (above 125 psig).
- Low pressure gaseous oxygen (below 125 psig).
- Atmospheric pressure gaseous oxygen.

Pressure gauges and other equipment provided by an approved manufacturer of oxygen equipment may be used provided they have been cleaned and packaged according to the specifications of this document and documentation is provided by the manufacturer attesting to such.

For other fluid systems requiring precision cleaning, the Process Systems Branch shall be available to assist in making the appropriate recommendation in accordance with Table 1.1.

Since most nonmetallic materials are highly combustible in oxygen service, it is necessary that all components and assemblies be cleaned of all contaminants and kept in this condition until the equipment is delivered to its final destination.

The cleaning process removes all contaminants such as loose scale, rust, grit, filings and other foreign particles, as well as oil, grease, and other organic materials. Special attention, as outlined in this LPR, shall be paid when cleaning subassemblies that have threaded joints; press or shrink fits; dead-end spaces, pockets, and small recesses; or are assembled in such a manner that later cleaning or inspection would be difficult.

Table 1.1, Classification of Surface Cleanliness Levels.

Particulate Matter Contamination Levels			NVR Contamination Levels		Visible Contamination Levels		
Level	Particle Size Range (micrometer)	Maximum Number of Particles per 0.1 m ² *	Level	Maximum quantity of NVR (mg. per 0.1 m ²)	Level	Definition	
25	<5 5 to 15 >15 to 25 >25	Unlimited 19 4 0	A	1.0	GC (Generally Clean)	Freedom from manufacturing residue, dirt, oil, grease, etc.	
50	<15 15 to 25 >25 to 50 >50	Unlimited 17 8 0	B	2.0			
100	<25 25 to 50 >50 to 100 >100	Unlimited 68 11 0	C	3.0			
150	<50 50 to 100 >100 to 150 >150	Unlimited 47 5 0	D	4.0	VC (Visually Clean)	The absence of all particulate and nonparticulate matter visible to the normal unaided eye or corrected-vision eye	
200	<50 50 to 100 >100 to 200 >200	Unlimited 154 16 0	E	5.0			
250	<100 100 to 200 >200 to 250 >250	Unlimited 39 3 0	F	7.0	UV (Visually Clean Plus Ultraviolet)	Visually clean and inspected with ultraviolet light.	
300	<100 100 to 250 >250 to 300 >300	Unlimited 93 3 0	G	10.0			
500	<100 100 to 250 >250 to 500 >500	Unlimited 1073 27 0	H	15.0			
750	<250 250 to 500 >500 to 750 >750	Unlimited 205 9 0	J	25.0			
1000	<500 500 to 750 >750 to 1000 >1000	Unlimited 34 5 0					

* No silting permitted

1.3. SAFETY AND PRECAUTIONS

This LPR specifies the use of materials, processes, and equipment that may be hazardous, toxic, and/or detrimental to the environment. This LPR does not address all of the environmental, health, or safety problems associated with the use of these materials, processes, and equipment. It is the responsibility of the user of this LPR to determine and establish environmental, health, and safety practices that are in compliance with Federal, state, and local regulations.

1.3.1. High-pressure Systems

High-pressure systems constitute a hazard in themselves in addition to the hazards involved when hydrocarbons are present in an oxygen-rich environment. The failure of a container charged with high-pressure gas may result in an explosion and fragmentation of the container. Additional information about high-pressure systems can be found in LPR 1710.40, "Safety Regulations Covering Pressurized Systems."

High-pressure gases shall receive particular attention to provide for a safe system. As a gas is compressed, energy is added and it heats due to several factors, i.e., compression and frictional forces associated with container boundaries. If a hydrocarbon lubricant is present in an oxygen-rich system, a condition is approached similar to that found in diesel engines and ignition may occur. Consequently, the only way to eliminate the possibility of ignition, fire, and explosions is to eliminate the fuels in high-pressure, oxygen-rich, gas systems.

1.3.2. Noise

Noise associated with "bleed off" or pressure relief of high-pressure gas reservoirs through a small orifice can reach sound pressure levels of sufficient intensity to cause acute damage to the ear with a resultant loss of hearing. Since acoustical control of this noise is impractical, personnel shall wear hearing protection when exposed to hazardous noise levels.

1.3.3. Vapor Concentration

The chemicals prescribed in this LPR shall be stored in ventilated areas. If large amounts of cleaning chemicals/solvents are permanently stored in an inhabited work area, oxygen sensors shall be installed. Also, the user shall refer to the appropriate Material Safety Data Sheet for additional information on hazards and required protection for any chemical prescribed in this LPR.

Trichlorotrifluoroethane is a solvent often used in cleaning equipment for oxygen service. At high concentrations, its vapor is hazardous to personnel. The American Conference of Governmental Industrial Hygienists (ACGIH) states that the Threshold Limit Value (TLV), the maximum concentration of trichlorotrifluoroethane vapor in air to which workers may be safely exposed over a normal eight hour working day, is 1000 ppm. Unprotected workers (i.e., a worker not wearing personnel protective equipment) shall not exceed the TLV at any time. Although

normal air movement is usually sufficient to keep vapors below this threshold limit, the atmosphere shall be monitored to ensure that safe limits are not exceeded. Additional ventilation may be required to maintain exposure levels below allowable limits. If necessary, personnel air lines shall be used.

1.4. REFERENCES

NSS 1740.15, "NASA Standard for Oxygen and Oxygen Systems."

Chapter 2**2. REQUIREMENTS****2.1. GENERAL**

All parts, components, assemblies, subsystems, systems, or related equipment requiring cleaning shall be disassembled, cleaned and inspected in accordance with this LPR. Quality assurance provisions for inspection and testing for the acceptance of parts, components, assemblies, subsystems, systems, and other related equipment that have been cleaned shall be as specified herein. Flow cleaning of assembled components is not allowed because fluid will interact with lubricants and soft goods, and/or become entrapped. Any part or component that might be damaged during cleaning shall be removed, disassembled, and cleaned as a separate item. Cleaning or disassembly operations on components shall be performed only by competent personnel who have demonstrated the capability of performing the necessary operations.

Materials, especially test fluids, shall be recycled where applicable. Test fluids shall be considered as in-process recyclable materials as long as the nonvolatile residue (NVR) level does not exceed 200 milligrams per liter (mg/L). Test fluids with NVR levels in excess of 200 mg/L and recycling still-bottom residues shall be made available for other reuse/recycling activities or disposed of in accordance with Federal, state, and local regulations.

2.2. PREPRODUCTION CLEANING AND PRESERVATION PROCESS APPROVAL

A statement containing the following information shall be submitted to the Process Systems Branch prior to performing any cleaning under this procedure:

- Processing materials to be used. This shall include trade names and specifications.
- Cleaning procedures to be used.
- Quality assurance provisions to be used. This shall include in-process control procedures to control contamination or latent corrosion, or both.
- Preservation and protection methods and materials to be used.
- Waste management and disposal procedures.
- Safety equipment and emergency procedures.

2.3. CLEAN ROOM AND WORK STATION REQUIREMENTS

Clean room facilities and workstations used for cleaning, validation, and packaging of cleaned items shall meet the requirements of FED-STD-209. The clean room level shall be consistent with the cleanliness level requirements of the item being cleaned.

2.4. MATERIALS

Test solvents and packaging films shall be used, as specified below.

2.4.1. SOLVENTS

2.4.1.1. Trichlorotrifluoroethane (Freon 113)

Trichlorotrifluoroethane used as a test solvent shall conform to MIL-C-81302, Type I.

Trichlorotrifluoroethane is a nonflammable solvent. However, it shall not be used near open flames, welding, or high temperature because high temperatures will result in the solvent vapors decomposing into toxic and corrosive products.

Trichlorotrifluoroethane shall not be used with rubber, plastic, or coated components with which it is not compatible. Incompatibility may result in change in polymer structure and molecular weight, dissolution of plasticizers and an increase in brittleness, swelling, and so forth. Where specific information with respect to compatibility is lacking, tests are to be conducted. Compatibility tests shall consist of immersion of test specimens in the cleaning compound at 80 ± 9 °F for 16 ± 1 hour. Conditions of immersion and testing shall be in accordance with ASTM D 1414-72 and ASTM D 471-79. Test specimens shall be completely surrounded by the fluid during immersion. Fluid volume shall be not less than 12 times the total volume of the specimen. Tensile strength, elongation, and hardness shall be determined by the "Properties After Evaporation of Test Liquid" method of ASTM D 471-79. Test requirements to establish compatibility are:

- Volume change, percent - minus 0 %, plus 10%.
- Retention of tensile strength, percent, minimum - 85 %.
- Retention of ultimate elongation, percent, minimum - 85 %.
- Change in durometer hardness, points maximum - plus or minus 5 %.

2.4.1.2. Isopropyl Alcohol

Isopropyl alcohol used as a test solvent shall conform to TT-I-735, Grade A.

2.4.1.3. Ethyl Alcohol

Ethyl alcohol used as a test solvent shall conform to O-E-00760.

2.4.2. CLEANING AGENTS

2.4.2.1. Brulin 815 GD

Brulin 815 GD shall be used for aqueous cleaning of components.

2.4.2.2. Brulin 1990GD

Brulin 1990GD shall be used for aqueous cleaning of pipes.

2.4.3. DEIONIZED WATER

Deionized water used as a cleaning solvent or in aqueous detergent cleaning shall conform to JSC-SPEC-C-20C, Grade A, with a pH between 5.0 and 8.0.

2.4.4. PACKAGING FILMS

2.4.4.1. Polyethylene

Polyethylene film for packaging shall meet the requirements of L-P-378, Type II, and Section 2.9.

2.4.4.2. Fluorohalocarbon

Fluorohalocarbon films such as Aclar 33C or equivalent for packaging shall conform to AMS 3649 and Section 2.9.

2.4.5. TAPE

Tape used for packaging shall conform to PPPT66, Type I, Class B.

2.4.6. DRYING AND TESTING GAS

Nitrogen gas for drying and testing of items shall conform to MIL-P-27401, Type I, Grade A.

2.5. MATERIALS TO PREVENT SEIZING, GALLING, AND FOR SEALING

Materials to prevent seizing, galling, and for sealing shall be in accordance with 79K09560 or 79K09561 (Kennedy Space Center documents) for liquid or gaseous oxygen, respectively. Some examples for use in both liquid and gaseous oxygen follow:

- Lubricants:
 - ☐ Krytox 143AC
 - ☐ Tribolube F195
 - ☐ Tribolube 16
 - ☐ Krytox 240AC
- Gaskets:
 - ☐ Viton
 - ☐ Teflon
 - ☐ Kel-F
- Thread Sealants:
 - ☐ Teflon Tape - Use only tapes made from pure virgin Teflon or other brand of tetrafluoroethylene polymer. For best results, threads shall be well cut. Teflon tape shall not be used on dead-ended, unsupported members in areas of extreme vibration, because of the possibility of backing off. Apply tape to the male threads, starting two threads in from the end of the pipe or fitting to prevent shredding. Wrap in the direction of the threads, and overlap one-half turn (on 2-inch and larger pipe, overlap a full turn).

Other materials shall not be used as thread sealants unless written approval of the Systems Engineering Competency is obtained.

2.6. FIELD CLEANING

Field cleaning is often complex because the size and configuration of large items make it difficult to circulate or spray solutions and to remove them completely. Precleaning operations such as pickling and passivating should be accomplished prior to installation. Used systems shall be disassembled into subsystems or subassemblies whenever possible for cleaning.

2.6.1. Preparation Prior to Field Cleaning

2.6.1.1. Component Removal

All subsystems, systems, or other related field equipment components that would entrap fluids or be harmed if subjected to the cleaning process when left in place shall be removed prior to cleaning. These removed components shall be disassembled, cleaned, and tested in accordance with Section 2.6.3. All removed components shall be replaced by temporary hardware.

2.6.1.2. Installation of Temporary Hardware

All temporary hardware necessary to perform or validate the cleaning process shall be compatible with the processing materials and the subsystem, system, or other related field equipment that is to be cleaned. All surfaces near openings resulting from the removal of components shall be visibly clean of contamination such as dirt, scale, and grease prior to the installation of temporary hardware.

2.6.1.3. Cleaning of Temporary Hardware

Temporary piping and components, which are required for system flushing and testing, shall be cleaned as specified for system piping prior to each use and tested in accordance with Section 2.6.1.6.

Interconnected piping and components in the piping systems shall be cleaned and maintained clean.

2.6.1.4. Marking of Temporary Hardware

All temporary hardware installed in or attached to an item to be cleaned shall be legibly marked as temporary hardware to ensure its removal from the item prior to final acceptance.

2.6.1.5. Leak Testing Prior to Cleaning

The integrity of the subsystem, system, or other related field equipment shall be validated by a pressure leak test, using water or a solvent after the installation of all temporary hardware and prior to the beginning of the cleaning process. The test pressure shall be 110% of the maximum anticipated cleaning process working pressure, and shall be held for a minimum of five minutes. Under no circumstances shall the proof-test pressure of the original subsystem, system, or other related field equipment be exceeded. Should a pneumatic test be

conducted, refer to LPR 1710.40, "Safety Regulations Covering Pressurized Systems."

2.6.2. Field Cleaning Equipment

2.6.2.1. Closed-Loop Cleaning Equipment

The following equipment shall be provided for cleaning and testing subsystems, systems, or other related field equipment by circulation of cleaning media in a closed loop:

- Containers of sufficient capacity to store, retain, or recirculate the process materials used on the item being cleaned.
- Heating and heat transfer equipment having sufficient capacity to control and maintain the specified temperatures of the process materials at the flow rates used. There shall be no dilution of solutions during heating.
- Circulating pumps, valves, and other components of sufficient size and capacity to minimize pressure losses in the cleaning system and capable of maintaining the required flow rates. Cleaning fluids shall be flowed at a minimum of 4 ft/s to assure satisfactory cleaning of the subsystems, systems, or other related equipment.
- Calibrated flowmeters, if specific flow velocities are used, of sufficient size to measure the liquid flow rates.
- Calibrated pressure gages capable of interpretation in the middle 60% of the scale and accurate to 1% of full scale.
- Filter to maintain the cleaning solution to a 10-micron absolute level.
- Receiving vessels of sufficient volume for the spent cleaning/rinse solution.

2.6.2.2. Spray Equipment

In addition to the equipment specified in Section 2.6.2.1, spray equipment such as spray wands and rotating-head spray machines shall be provided for impinging process solutions on and wetting all internal surfaces of large items such as storage vessels or large-diameter pipes that cannot be cleaned by closed-loop circulation. Spray equipment shall be capable of delivering process solutions to provide a spray pattern that forcibly impinges process solutions on and completely wets the entire interior surface of the item being cleaned.

2.6.3. Field Cleaning Procedures

2.6.3.1. Precleaning

All critical surfaces of subsystems, systems, storage vessels, or other items in the field shall be visibly free of corrosion, dirt, grease, scale, or other foreign matter prior to final cleaning. Precleaning shall be performed by using one or more of the following techniques:

- Mechanical cleaning.

- Solvent wipe.
- Detergent scrub.
- Detergent flush.
- Acid treatment.
- High-pressure wash.
- Detergent spray.

2.6.3.2. Mechanical Cleaning

This method shall be used only when contaminants so generated can be removed and when physical damage to the item being cleaned will not occur. Mechanical cleaning shall be accomplished by brushing, shot peening, grit blasting, tumbling, or grinding. Corrosion-resistant steel surfaces shall be cleaned by brushing with a corrosion-resistant steel brush, grinding, or using an abrasive material.

Abrasive materials used on corrosion-resistant steel surfaces shall not contain ferrous or ferric materials. The use of the same corrosion-resistant steel brush for corrosion-resistant steels and carbon steels shall not be permitted. All loose dirt, scale, and other debris shall be completely removed from the item by vacuum cleaning, brushing, blowing, or flushing with clean water.

2.6.3.3. Cleaning By Closed-Loop Circulation of Solution

The circulation of the cleaning solution in a closed loop shall be used only on items in which the total volume can be filled by the solution and all critical surfaces can be wetted by the solution. Where possible, adequate low point drains shall be installed to prevent entrapment of fluid or particulates. Equipment for use in closed-loop circulation shall meet the requirements of Section 2.6.2.1.

2.6.3.4. Cleaning By Solution Spraying

Items having a size or configuration that cannot be cleaned by circulating a fluid through the item shall be cleaned by the use of spray equipment. Equipment for use in solution spraying shall meet the requirements of Section 2.6.2.2.

2.6.3.5. Final Cleaning/Verification

Final cleaning shall be accomplished using trichlorotrifluoroethane, per Section 3.9, solvent flush sampling, piping. Trichlorotrifluoroethane complying with MIL-C-81302, Type I, shall be used as the final cleaning and testing medium for oxygen systems. Approval shall be obtained from the government representative before the final flush is performed.

The background contamination level of the trichlorotrifluoroethane cleaning solvent shall be checked prior to use in oxygen piping systems. The background matter contamination level shall not exceed level 200 (Table 1.1).

2.6.3.6. System Dryness

After the final flush and the system is certified clean, the system shall be dried with dry nitrogen gas and tested for dewpoint as per Section 3.6.

2.6.3.7. Work Flow

All steps in precleaning procedures shall progress in an uninterrupted workflow through the final rinse and drying operation. If the workflow is unavoidably interrupted, the precleaning procedure shall specify a recycling operation. Precleaning procedures shall include, as a minimum, protection of the item by interim packaging or other approved means to prevent recontamination through all subsequent operations.

2.7. COMPONENT CLEANING AND FUNCTIONAL TESTING

The cleaning of an oxygen system shall begin with disassembly to the elemental or piece part level. If cleaning is attempted by flowing solutions through a component, vulnerable internal elements may be damaged by the solution required to clean the major elements of the component. Also, contaminants and cleaning solutions may become entrapped in component recesses and may ultimately react with oxygen. When the component has been disassembled, the parts shall be grouped according to the method of cleaning. Special cleaning procedures shall be developed to remove entrapped contaminants. Disassembly also allows assessment of the serviceability of the component elements. If sealing surfaces are damaged or cracks are observed in the metallic parts, the component shall be repaired or replaced. Special attention shall be directed to the component soft goods. Damaged or worn soft goods shall be replaced.

Cleaning or disassembly operations of precision components that might affect tolerances or impair calibration shall be performed only under the supervision of personnel qualified in the handling, calibration, and/or assembly of the components.

When individual parts of an assembled component have not been cleaned prior to assembly, the assembled component shall be rejected and reprocessed for cleaning, disassembly, rework, and retesting.

A functional test of the components shall be conducted after reassembly. Testing shall be documented on appropriate component functional test report forms.

Trichlorotrifluoroethane shall not be used for component cleaning without the concurrence of the Process Systems Branch.

2.7.1. Precleaning Procedures

Each item requiring precision cleaning shall be precleaned (rough cleaned) to the VC level prior to its placement in a clean room or clean work station.

2.7.2. Precleaning Process Controls

Precleaning of parts shall accomplish the removal of all visible contaminants without removing or changing the characteristics of the base materials. All traces of precleaning materials shall be removed from the parts at the completion of the

precleaning process to prevent the future formation of mineral salts and corrosion products. Tests, such as pH testing, shall be used to verify removal of all residuals.

2.7.3. Rough Cleaning

All critical surfaces of subsystems, systems, storage vessels, or other items in the field shall be cleaned to remove corrosion, dirt, grease, scale, or other foreign matter prior to precision cleaning.

2.7.4. Precision Cleaning

Precision cleaning shall be performed in a controlled environment and is intended to remove particles, films, biological forms, and other forms of contaminants that are usually not visible but could degrade the product or process. The level of precision cleanliness shall be verified and evidence of inspection and acceptance shall be provided. Precision-cleaned articles shall be packaged immediately after verification of cleanliness or suitably protected prior to leaving the controlled environment. Precision-cleaning solutions or material shall not react with, combine with, etch, or otherwise cause immediate or latent degradation of the item being cleaned. Precision-cleaning fluids shall be filtered and controlled. Their cleanliness level shall be verified as being sufficient to achieve the specified product cleanliness as specified by Chapter 3, "Quality Assurance and Verification Provisions."

2.7.5. Types of Precision Cleaning

2.7.5.1. Mechanical Cleaning

Mechanical cleaning shall be used only when contaminants generated can be removed and when physical damage to the item being cleaned will not occur. Mechanical cleaning may be accomplished by brushing, shot peening, grit blasting, tumbling, or grinding. Corrosion-resistant steel surfaces shall be cleaned by brushing with a corrosion-resistant steel brush, grinding, or using abrasive material. Abrasive materials used on carbon steels shall not be reused on stainless steels. All loose dirt, scale, and other debris shall be completely removed from the item by vacuum cleaning, brushing, blowing, or flushing with clean water.

2.7.5.2. Mechanical Descaling

Mechanical descaling removes contaminants by abrasive action. This method shall be used only when contaminants generated by this abrasive action can be removed or when physical damage to the item being cleaned will not occur.

Mechanical descaling shall be accomplished by brushing, shot peening, grit blasting, vapor honing, tumbling, or grinding. Surfaces that contain scale and/or oxides and all steel or stainless steel welds that will be exposed to gas or liquid

and are accessible shall be thoroughly cleaned with a stainless steel wire brush, grinder, or abrasive material. Carbon steel surfaces may be shot blasted.

Using the same stainless steel wire brush for carbon steel and stainless steel is forbidden. Material to be used for abrasive cleaning stainless steel surfaces shall contain no ferrous or ferric materials.

Internal surfaces of pipe may be cleaned by a “go-devil” type of device with a grinder of 150 grit abrasive or finer. All loose dirt, abrasive, or scale shall be completely removed from components by vacuum cleaning, blowing, brushing, or flushing with clean water. Components whose welds are not accessible for mechanical descaling shall be descaled by picking. All pipes shall be further descaled by acid pickling.

2.7.5.3. Vapor Degreasing

Soluble organic contaminants (e.g., oils, greases, hydrocarbon fuels, etc.) are readily removed by vapor degreasing. Vapor degreasers use solvent vapors to chemically dissolve and use condensate to remove solvent soluble contamination. Parts to be vapor degreased shall be processed in a standard commercial degreaser or degreasing vapors shall be blown into the component parts so that the vapor will condense on and properly degrease all surfaces. The operation of the commercial vapor degreaser shall be in accordance with the manufacturer’s recommendation.

The steps normally followed in vapor degreasing parts are as follows:

- The work piece is lowered into the vapor zone of the degreaser.
- The solvent vapor condenses on the cooler parts, dissolving the contamination.
- The condensed vapor flows down over the part, carrying the contamination to the boiling liquid in the bottom of the tank.
- Condensation ceases when the part reaches vapor temperature.
- The part is raised from the degreaser and it immediately dries.

Vapor degreaser limitations and cautions are listed in Table 2.1.

Table 2.1, Vapor Degreaser Limitations And Causes.

VAPOR DEGREASER LIMITATIONS AND CAUSES		
Subject	Limitation or Caution	Recommendations
Acidity	Solvent may decompose, become acidic, and attack copper, titanium, aluminum, and magnesium; chlorides by decomposed solvents and aluminum or magnesium will further contaminate electronic components.	Periodically check solvent acidity; follow prescribed degreaser cleaning schedule; use different degreasers for aluminum or magnesium and electronic components.
Rust	Degreased ferrous parts are highly susceptible to oxidation.	Provide clean, dry atmospheres; apply rustproofing solutions.
Heat	High solvent temperatures are deleterious to some materials such as rubber and plastic. Certain polishing and buffing compounds may bake on parts at high solvent temperatures.	Check maximum safe temperatures before exposing to solvents. Use spray vapor cycle, or soak or flush with other solvents and hand brush prior to degreasing.
Chlorides	Chlorides formed by decomposed solvents and certain metals (aluminum, magnesium, beryllium) will attack some electronic components, rubbers, and plastics, as well as the metals themselves; do not use chlorinated solvents with titanium.	Check chloride effect on nonmetals; provide proper degreaser maintenance; consider separate degreasers for electronic components.
Thin-walled parts	Part temperature may increase to vapor temp quickly so that desired cleanliness is not achieved.	Use vapor / spray / vapor cycle or cool and repeat vapor cycle.
Large parts	Part may be too large for available degreaser.	Degrease a portion at a time; hand clean with solvents.
Blind holes	Depth, location or orientation may present cleaning or draining problems.	Use vapor / spray / vapor cycle; ultrasonic plus vapor; rotate part to permit drainage.
Convoluted parts and tubing	Solvents and dissolved contamination may become trapped in convolution or torturous passages.	Parts shall be fixed to rotate during degreasing and drying; a solvent pressure flush may be required.
Metal castings	Due to micro- and macro-porosity, all contaminants may not be removed from the pores; prevents proper impregnation; may subsequently weep oil.	If no insoluble contaminants are present, recommend oven bake and combination of ultrasonic-vapor degreasing cleaning.
Oil impregnated powder metal parts	Bearings and bushings may be oil - impregnated for the life of the part; degreasing will remove portions of this lubricant.	If cleaning is required, mild solvent surface wipe or brush; or completely degrease and reimpregnate.

2.7.5.4. Ultrasonic Cleaning

The removal of surface soils by forces created through the implosions of vapor bubbles (cavitation) is known as ultrasonic cleaning. The pulsating sound waves create three phases in the cleaning solution:

- Degassing - Large bubbles or voids form as a result of high negative pressure on the fluid. The bubbles combine, become buoyant, and rise out of solution.
- Pulse - gaseous bubbles 40 microns or less pulsate several thousand times per second, causing a scrubbing action.
- Collapse - The positive pressure of the liquid reacts on the vapor filled bubbles, which collapse and leave a void. The liquid rushes in and creates tremendous heat and pressure at the location of the bubbles (20,000 °F and 10,000 psi). The suction or vacuum of these implosions pulls soil from the component.

The operational factors below shall be observed to ensure effective sonication.

- Cleaning solution - Select the proper cleaning solution for the cleaning job to be done. Liquid levels shall be adequate to prevent damage to the ultrasonic unit.
- Degassing - Any solution shall be degassed before use. Complete degassing time depends on the properties of the solution, especially temperature, tank depth, power intensity, and type of pulse. Shallower tanks, higher solution temperatures, and higher power intensity with a pulsed wave allow faster degassing. Soft or deionized water is more easily degassed than hard water. Partial degassing (80-85%) shall take place in about five minutes. Complete degassing shall occur after about 30 minutes, but the time may vary on the above factors. Heating the solvent to within three to five degrees of its boiling point will also accomplish degassing.
- Immersing Parts - Slow immersion and removal of parts from the cleaning solution will prevent the introduction of air and the bouncing back of reflective ultrasonic waves to the transducer and generator. Parts shall be withdrawn from the tank while the cleaner is operating. If the ultrasonic tank emits sharp screeching sounds, the parts are being introduced too fast and the generator is being put under undue stress.
- Parts loading - Load parts in the ultrasonic cleaning tank such that neither the part nor the parts basket is on the tank bottom. Heavy parts (high mass) shall each be exposed to direct ultrasonic waves. If they are stacked on top of each other, the top parts may not get cleaned. The sum of the parts cross-sectional area shall not exceed 75% of the tank cross sectional area. For most effective cleaning, total parts weight shall not exceed .351kb/Kw of generator power, even though a slightly higher weigh to Kw ratio can be accommodated. Elastomers and nonrigid plastics will absorb ultrasonic

energy and will produce a shadowing effect; insulated parts may have to be specifically oriented.

- Container design - Incorrect basket design or a basket having too high a mass can greatly reduce the effectiveness of the best ultrasonic cleaning system. Any material more tightly woven than 50 mesh screen acts as a solid sheet, while slightly larger openings scatter the ultrasonic waves; openings larger than 0.25" act as open material. Hooks, racks, and beakers can also be used to support parts.
- Parts positioning - Parts positioning, important in most cleaning operations, is doubly important in ultrasonic cleaning. If possible, critical areas to be cleaned should face the transducer, but racked parts should be positioned vertically, rather than being stacked one on top of the other. Care shall be taken so that air is not trapped in blind holes, thereby preventing liquid contact with all surfaces. Parts shall be covered by at least 0.75" of cleaning fluid and, if possible, shall be positioned at the correct depth to take advantage of the higher intensity at the anti-node of the ultrasonic wave.
- Noises - Audible noises of two types may be produced. A buzzing or hissing noise is caused by the shock waves produced by cavitating bubbles; screeches or squeals resulting from "beat notes" should be avoided. Beat notes can be caused by moving parts too fast in the tank, too violent agitation of the liquid, resonant bubbles, or two or more non-synchronized generators. Introduction of a parts basket or parts into the liquid will usually eliminate beat notes from these causes. Beat notes may also be caused by cleaning chemicals, which do not form clear solutions or by excessive accumulation of greasy soils, which are not completely soluble in the solution used. If this occurs, use a different solution or change the solution more frequently.
- Filtering - In precision cleaning, particulate matter shall be removed from the cleaning fluid. This may be done with a continuously re-circulating filtration system simultaneously with ultrasonic cleaning. The rate of flow through a filter system shall be determined through experimenting with each cleaner. A depth filter shall precede the absolute filter for maximum practical effectiveness. The rate of flow is generally not over one to three percent of the tank volume per minute, as too high a rate will prevent the cavitation process by creating turbulence and may produce screeching sounds.

2.7.5.5. Detergent Degreasing

Alkaline cleaners and detergents shall be used for removing organic and inorganic contamination, which can be removed by solution or emulsification (e.g., oils, fat, shop soils, grease, etc.). Components shall be degreased in a solution of detergent and water. Surfaces of the component shall be swept with a soft nylon brush. Detergent degreasing can also be done in an ultrasonic cleaner.

Components shall be first rinsed with tap water followed by a de-mineralized water rinse. Components shall then be oven dried.

2.7.5.6. Alkaline Degreasing

Components may be degreased with commercial alkaline cleaners. The components shall be filled, immersed, sprayed, or scrubbed with the particular alkaline cleaner in accordance with the manufacturer's recommendations.

2.7.5.7. Acid Pickling

Acid cleaners shall be used to remove contamination not soluble in other solutions (e.g., weld scale, corrosion products, oxide film, etc.). Components, which contain rust, scale, weld splatter, or other foreign material after degreasing, may be pickled.

Mechanical cleaning shall not be done after pickling.

2.7.5.8. Passivation

All components shall be rendered passive. Passivation solutions prevent corrosion and are treatments supplementary to acid, alkaline, and mechanical cleaning. Protect passivated surfaces from scratching, nicking, abrasion, etc.. Passivation should not be confused with conversion films or other protective film processes.

2.7.5.9. Drying

Drying shall take place immediately after the final rinse, using nitrogen gas, oven drying, or vacuum drying. Drying gas shall conform to Section 2.6.3.6.

2.7.6. Special Cleaning: Nonmetallic Materials

For the purpose of this document, nonmetallic materials include natural rubber, Teflon, Kel-F, polyethylene, polycarbonates, and other plastics or synthetic materials. Caution shall be taken to insure that the cleaning solution used in the method will not adversely affect the materials, i.e., external damage, or absorption of the cleaning solution and consequent outgassing.

The following method or its equivalent is acceptable for cleaning nonmetallic materials:

- Decontaminate using a cold tap water flush until the pH of the effluent is within one-half of a pH unit of the influent.
- Detergent clean with a biodegradable nonionic detergent using nylon brushes as necessary.
- Spray rinse with tap water (150 to 180 °F), followed by a rinse with deionized water that has a minimum specific resistance of 50,000 ohms.
- Dry with nitrogen gas (at approximately 140 °F).

2.7.7. Special Cleaning: Transducers, Temperature Sensors and Flow Meters

2.7.7.1. Precleaning

Clean the exterior with clean, lint free cloth dampened with trichlorotrifluoroethane. Encase the item in a polyethylene bag and tape seal so that only the sensing part(s) or surfaces are exposed. Using a wash bottle filled with high purity water, flush interior of transducer and flush exterior sensing surfaces of temperature sensors. Use fill and drain method to flush fluid passageways of flowmeters. Flush items until effluent water is visibly clear of discoloration and particles, and the pH is within one-half pH of the influent. Dry with hot (140 °F maximum) nitrogen gas. Hold the gaseous nitrogen wand at a minimum distance of one foot from the item to provide ventilation of the item only and to prevent pressure buildup in the sensing chamber or bending of small diameter temperature sensing probes.

2.7.7.2. Solvent Cleaning

Use precision cleaning solvent (MIL-C-B1302, TYPE 1), instead of water, and continue flushing until the effluent is visibly clear of discoloration and particulates. Examine the sensing chamber of transducers for visible contamination on the diaphragm or threads. Examine temperature sensors for visible contamination on threads and sensing surfaces. Inspect fluid passageways, vent holes, vanes, etc., for visible contamination. If visible contamination is evident, continue flushing.

Do not introduce a brush, probe, thread chaser, or any device, metal or plastic, into the sensing chamber of a transducer to dislodge contaminants from the sensing chamber or from the sensing port threads.

Dry with nitrogen gas (140 °F maximum) as outlined in the precleaning procedure above.

Use of trichlorotrifluoroethane on components is authorized only by a special waiver from the Systems Engineering Competency.

2.7.7.3. Final Cleaning

Flush sensing chambers, probes, threads, or fluid passageways and surrounding areas with precision cleaning solvent that has been passed through a 5-micron absolute filter. Continue flushing for one minute or until areas and effluent are visibly clear of contamination. Repeat, using Freon that has passed through a 0.5-micron filter.

2.7.7.4. Drying

Dry with nitrogen gas (140 °F maximum) as outlined above.

2.7.8. Special Cleaning: Smooth Bore Hoses and Tubing

2.7.8.1. Precleaning

Examine hoses or tubes for evidence of kinks, bends, or thread damage. Decontaminate by immersion or flush rinsing with cold tap water until pH of effluent is within 0.5 pH of the flushing medium.

2.7.8.2. Detergent Cleaning

Detergent clean exterior surfaces of hoses or tubing with nonionic biodegradable detergent cleaner using nylon brushes as required. Exposure time, temperature (not to exceed 145 °F), and concentration shall conform to manufacturer's recommendations. Rinse with tap water. Dry with hot (120 to 140 °F) nitrogen gas as per sections above. Carefully clean end fittings of hoses and tubes with solvent, MIL-C-B1302, TYPE 1, using nylon brushes as required. Care shall be taken to assure that the solvent does not contact the hose. Install adapter fitting and connect hose or tube to be cleaned, to the pump discharge line. Install a restrictor fitting in the downstream end of the hose or tube being cleaned. This provides back pressure so cleaning and rinsing solutions will contact all interior surfaces.

2.7.8.3. Cleaning of Hose Assemblies

Flush hose with nonionic biodegradable detergent cleaner for 5 to 15 minutes. Change flush pump suction to deionized water that has a minimum specific resistance of 50,000 ohms and flush for one to two minutes. Detach the hose from the flush pump discharge hose and remove all adapter fittings. Thoroughly rinse end fittings of the hose with deionized water. Dry in heated (120 to 140 °F) vacuum chamber for 25 to 35 minutes at maximum vacuum.

2.7.8.4. Final Rinse and Cleaning

Flush rinse hoses or tubes with 0.5 micron filtered solvent, MIL-C-B1302, TYPE 1. The rinse fluid for nonmetallic items shall be deionized water. The flow of fluid at the downstream end of the hose shall be restricted as necessary to provide fluid contact with all interior surfaces of the hose or tube. After completion of the final rinse, continue the rinse and collect 100 ml of fluid per square foot of the interior surface of the hose or tube. Dry interior surfaces and end fitting with 10 micron absolute filtered hot (120 to 140 °F) nitrogen gas as per sections above.

2.7.9. Inspection

Prior to precision cleaning and cleanliness verification, all items shall be inspected to the VC level as stated in Section 3.3.

2.7.10. Final Cleaning

All final cleaning shall be performed in a clean room environment following precleaning operations described herein. The items to be precision cleaned shall be flushed or wiped with solvent as specified in MIL-C-B1302, TYPE 1, with the

exception of Section 2.7.6, and/or vacuum cleaned or blown off with clean dry nitrogen to prevent the entry of gross contaminants into the clean room environment. All final cleaning processes shall be as specified in Section 3.9.3.

2.8. RECLEANING OPERATIONAL SYSTEMS

Systems that have successfully passed the specified quality assurance tests for initial acceptance and have been placed in operation shall be recleaned only when there is reason to suspect cleanliness has been compromised (dirty filter, system fluid doesn't meet specifications, component replacement or repair, visible contamination found when opening the system). Any need for retesting shall be determined and conducted by the Government.

2.9. PROTECTION OF CLEANED SURFACES

2.9.1. Environmental Control

All packaging operations involving cleaned surfaces shall be accomplished within the same controlled environment in which the item to be packaged was sampled. Outer protective wrap, such as dimple wrap, shall be applied outside the controlled area.

2.9.2. Protection Materials

Materials shall be compatible with items to be protected and shall be able to withstand the specified environment for the storage period and mode of delivery including impact protection of critical surfaces.

2.9.2.1. Metallic Closures

Metallic closure plates shall be used to seal flanged items and the materials shall be precut and drilled aluminum alloy or stainless steel with a minimum thickness of 0.125 inch. To prevent electrolytic corrosion, metals dissimilar to item flanges shall not come in contact with the flange. Refer to MIL-STD-889 for definition of dissimilar metals. All metallic closures shall be separated from the flanged item with gaskets. Gaskets shall be precut from a minimum of two layers of plastic film conforming to Section 3.2 or from a sheet of polytetrafluoroethylene of 0.062-inch minimum thickness. The cleanliness level of metallic closures and gaskets shall be at least equal to the level of cleanliness of the cleaned surfaces.

2.9.2.2. Preservatives

Preservative materials shall not be used on items that have been cleaned.

2.9.2.3. Desiccants

Desiccant materials shall not be used unless specified.

2.9.3. Packaging of Cleaned Items

2.9.3.1. Cutting

When clean plastic film is to be cut, stainless steel, chrome-plated, or nickel-plated scissors shall be used. The scissors cut shall be started, and the scissors shall be pushed carefully through the film. Sawing and hacking actions resulting from opening and closing the scissors shall be avoided to prevent the generation of particles. Razor blades or other single-blade type instruments shall not be used to cut plastic film.

2.9.3.2. Sealing

An all-purpose impulse sealer shall be used to produce effective seals with plastic films. The recommendations of the manufacturer shall be followed for temperature setting and dwell time. Fluorohalocarbon films such as Aclar 22A and 33C shall be sealed on all sides when fabricating bags. Fluorohalocarbon films are not to be center folded. Center folding may generate particles since Fluorohalocarbon films tend to be somewhat brittle.

2.9.3.3. Detailed Requirements

Small Items - Small items that have all surfaces cleaned shall be cushioned as applicable, bagged and sealed per Section 2.9.3.2. Threaded fittings shall be double-bagged and placed in a bubble bag. Sandwich packaging may be used with identical small and light items such as O-rings and gaskets. A sandwich package consists of heat sealing a number of identical items between two sheets of plastic film in such a manner that each item is in a separate heat-sealed compartment. Each compartment shall be separable from the others by cutting without violating the integrity of the remaining compartments. Each inner bag shall be placed in an outer bag of polyethylene with a tag in accordance with Section 2.10.

Items Internally Cleaned Only - Items that are cleaned internally only shall have all fittings and orifices leading to the internally cleaned surface sealed with plastic film. The plastic film shall be secured in place with tape conforming to PPP-T-66, Type I, Class B. The adhesive backing on the tape shall not come in contact with the body of the item. The sealed fittings or other orifices shall be cushioned with protective film. Small items that have been cleaned and sealed shall be placed in an outer bag of polyethylene and sealed in accordance with Section 2.9.3.2. Each sealed fitting or other orifice of large items shall be overwrapped with polyethylene. Identification shall be in accordance with Section 2.10. The use of plastic plugs and caps is prohibited.

Flanged Items - Flanged items that have only internally cleaned surfaces shall be sealed with gaskets and closures in accordance with Section 2.9.2.1. A cleaned gasket shall be placed over the flange face followed by placing the closure over the gasket. Attachment hardware shall be inserted through all the flange holes and

tightened to secure the closure. The completed closure shall be overwrapped with polyethylene and secured with tape conforming to PPP-T-66, Type I, Class B. The adhesive backing of the tape shall not come in contact with the flange face. Identification shall be in accordance with Section 2.10.

Electrical and Electronic Items - Electrical and electronic items that require testing after cleaning shall be packaged in an inner bag sealed in a manner that will permit access to test points such as leads and connectors without violating the integrity of the inner bag. Exposed items such as leads and connectors shall be cushioned as required. Each inner bag is to be placed in an outer bag of polyethylene, sealed, and identified in accordance with Section 2.10. Tamper-proof decals shall be applied to the outer bag in accordance with Section 2.10.

Hose and Tube Assemblies - Hose and tube assemblies that have only internally cleaned surfaces shall be sealed with plastic film. The plastic film shall be secured in place with tape conforming to A-A-1689A, Type I, Class B. The adhesive backing on the tape shall not come in contact with the body of the item. The entire hose or tube assembly may be overwrapped with polyethylene film as applicable.

2.10. IDENTIFICATION OF CLEANED ITEMS

Certification tags shall be placed between the inner and outer bags or layers of protective packaging film where practical. Where the tag cannot be placed between the inner and outer packaging film, the tag shall be enclosed in a plastic bag or between layers of plastic film and securely taped to the outside of the package. Tags shall be serviceable and of sufficient size to contain the following information:

- Part or identification number.
- Contractor identification (if applicable).
- Number and revision of contract specification (if applicable).
- Date of cleaning.
- Manufacturer's serial number.
- Software Material List.
- Cleanliness level of specification.

Chapter 3**3. QUALITY ASSURANCE AND VERIFICATION PROVISIONS****3.1. RESPONSIBILITY FOR INSPECTION**

The vendor supplying a product or services to the Government (LaRC) shall be responsible for the performance and documentation of all inspection and tests specified in this LPR, associated with that product or service. Inspection and test records shall be kept up to date and made available in accordance with the provisions of the contract. One copy of each shall be forwarded to the Office of Safety and Facility Assurance for review and approval. The government reserves the right to perform any or all of the inspections and tests set forth in this procedure to assure end item or services conform to all specified requirements.

When in-house services are provided, the appropriate inspections and tests shall be performed by the Government.

3.2. GENERAL

Quality assurance and verification provisions are subject to the same requirements stated in Section 2.1.

3.3. VISUAL INSPECTION

A visual observation shall be made with the unaided eye (corrective lenses are acceptable) under a white light of sufficient intensity to illuminate the surface being inspected. Visual examination of the direct surface under strong white light shall indicate:

- No evidence of moisture.
- Freedom of corrosion products.
- Freedom of loose (or potentially loose) dirt, scale, slag, weld spatter or other foreign matter.
- Freedom of organic material such as oil, grease, crayon, paint, etc..
- Scale-free discoloration due to welding and passivation is permitted.

Borescopes, mirrors, and other devices may be used to increase accessibility during inspection, but magnifying lenses may be used only to further identify visible contaminants. Where configuration, color, or other item characteristics interfere with visual observation, the following tests shall be used to augment visual inspection.

3.4. BLACK LIGHT (UV) INSPECTION

A visual inspection shall be made of the item with the unaided eye under UV light (having a power of at least 100 watts and 3,200 to 3,800 angstroms wavelength) for the presence of hydrocarbons. Accumulations of lint or dust that may be visible under the black light shall be removed by blowing with dry oil free nitrogen Mil-P-

27401C. Where the surface to be inspected is inaccessible, a Wipe Test shall be performed and the wiping medium shall be inspected under UV light.

Any contamination detected by the visual inspection or the black-light inspection shall be cause for rejection and recleaning. If recleaning fails to remove fluorescent indications, an investigation shall be made to determine if the item material is naturally fluorescent. If natural fluorescence cannot be established, the part shall be replaced.

Some contaminants, e.g., Krytox, do not fluoresce under black-light inspection. Therefore, black light shall not be the sole criteria for acceptance for oxygen cleaning.

3.5. WIPE TEST

If the surface to be inspected is inaccessible to Black Light Inspection, a Wipe Test shall be performed with a lint free medium, and the medium observed for the presence of contaminants. Care must be taken not to wipe too hard since soft metals, such as aluminum, will abrade and soil the medium, giving an erroneous indication of contamination. The wiping medium shall be subjected to visual inspection and the black-light test specified in Sections 3.3 and 3.4, respectively.

When the wiping medium is subjected to further tests, such as black light or hydrocarbon evaluation, a baseline reading of the black wiping medium must be determined and accounted for in subsequent evaluations.

3.6. DEWPOINT ANALYSIS

Dewpoint determinations shall be made using a calibrated dewpointer; initial reading shall be recorded. Maintain system or container under static pressure whenever feasible for a 15 minute interval. Reverify dewpoint reading. If the dewpoint temperature has increased more than 5 °F during the interim period, continue purging until the acceptable dewpoint is verified. GN used as a purging or drying medium must be filtered to meet the cleanliness level specified for the item being tested. Dewpoint of purge or drying gas must be -65 °F minimum. Effluent gas moisture content shall be 20ppm or less. Manufacturer's directions shall be followed for operation of the particular instrument.

3.7. ACIDITY AND ALKALINITY TEST

All surfaces that have been cleaned shall be tested for acidity and alkalinity with pH paper, or an approved calibrated meter, while the surfaces are wet from the final rinse water. Dry surfaces of completed items may be wetted with a few drops of distilled water to permit testing as required. Acceptable test results shall range between 6 to 8.

3.8. WATER BREAK TEST

The surface to be inspected shall be placed in the horizontal, face-upward position, if possible. The surface shall then be sprayed with distilled water from an atomizer to completely cover the area of interest. The presence of droplets or breaks in the water film is possibly an indication of oily hydrocarbons.

3.9. SOLVENT FLUSH SAMPLING - PIPING

3.9.1. Configuration

The system shall be intact and in its final configuration. Any part or component that might be damaged during the verification flush/rinse shall be removed, and if that removal would cause an opening/leak in the system, the leak shall be sealed by hand with a precision cleaned item.

3.9.2. Test Solvent

The test solvent shall be trichlorotrifluoroethane in accordance with MIL-C-81302, Type 1. This cleaning compound (CFC-113) has a strong attraction for hydrocarbons and samples of this compound can be inspected for total contamination to furnish positive indication that the nonvolatile residue (NVR) is within allowable limits when tested in accordance with Section 3.9.3.

3.9.3. Solvent Volume for Analysis

3.9.3.1. Test Procedure

The solvent-flush test procedure shall be as follows:

- Ascertain the total volume of test solvent necessary to flush the cleaned item or items.
- Flush all critical surfaces uniformly with the test solvent. Tubing, piping, and hoses are to be flushed at 4 ft/s (minimum).
- Catch the test solvent in a precision cleaned glass container.
- Immediately upon the completion of the above step, dry the tested items using the dry gas specified previously.

3.9.4. Particle Analysis of Solvent-Flush Sample

The solvent-flush sample shall be analyzed for particle population as shown in the following sections.

3.9.4.1. Particle Population Analysis (Microscope)

Particle population per square foot shall be determined on the basis of the critical surface area. The total volume of test solvent, or a representative sample of the test solvent not less than 100 ml, shall be analyzed as follows:

- Assemble a cleaned filtration apparatus.

- Using clean forceps with nonserrated tips, place a filter membrane (47-mm diameter with 0.45-micron pores) in position in the filter holder. The filter membrane must be compatible with the test solvent. Prior to insertion, the filter membrane may be rinsed with filtered test solvent to remove any adherent contamination.
- Fill the filter funnel approximately three-fourths full of test solvent and turn on the vacuum pump. Avoid splashes on sides of funnel.
- Add the remaining test solvent to the filter funnel at a rate necessary to maintain the funnel more than half full until all of the test solvent has been added. Do not allow the test solvent to pour directly onto the filter membrane after filtration has started.
- When filtration is completed, remove the filter membrane from the holder and place it in a disposable Petri dish or equivalent until the particles are counted. Do not subject Petri dish to jostling or turn it upside down as particles may fall off the membrane.
- Place the filter membrane under the microscope.
- Direct a high-intensity light source of 5,000 to 6,000 candelas onto the filter membrane from an oblique position to obtain maximum definition for sizing and counting. High-intensity illumination is a critical requirement.
- Use magnification of approximately 40 to 50 power for counting particles.
- Count the particles in accordance with the method of ASTM F 312 over the entire effective filtering area of the membrane.
- Calculate the particles per square foot (for items having less than 1 square foot of surface area, use 1 square foot) of the critical surface as follows:

$$\frac{\text{Particles}}{\text{ft}^2} = \frac{(\text{Particles counted}) \times (\text{total volume of test solvent used})}{(\text{ft}^2 \text{ of surface}) \times (\text{volume of sample filtered})}$$

- Particular matter contamination shall meet the cleanliness level specified in Table 1-1. Visible silting is cause for rejection. Place the filter in a small plastic bag with a sealable strip and attach to the report.

3.9.4.2. Particle Population Analysis (Automatic Particle Counters)

Automatic liquid-borne particle counters shall be used for final verification of cleanliness of the end product provided the individual counters have demonstrated accuracy and repeatability and their use is approved.

3.10. COMPONENTS

The components shall be disassembled to the elemental or piece part level. Several small parts shall be grouped together if they belong to the same cleaning order. Care shall be taken to avoid parts rubbing or crashing into each other.

3.10.1. Test solvent

3.10.1.1. Solvent Volume for Analysis

Use a minimum of 500 ml for test surfaces of 0.1 m² to 0.5 m². For surfaces that total less than 0.1m², assume surface equals 0.1m². For surfaces greater than 0.5 m², use 100-ml solvent for every 0.1m².

3.10.1.2. Test Procedure

The solvent-flush test procedure shall be as follows:

- Ascertain the total volume of test solvent necessary to flush the cleaned item or items.
- Flush all critical surfaces uniformly with the test solvent. Where flushing does not reach all interior surfaces, the test solvent shall be introduced and the item manually shaken.
- Catch the test solvent in a precision cleaned glass container.
- Immediately upon the completion of the above step, dry the tested items using the dry gas specified.

3.10.1.3. Analysis of Solvent-Flush Sample

Particle Population Analysis (Microscope) population per square foot shall be determined on the basis of the critical surface area. The total volume of test solvent or a representative sample of the test solvent not less than 100 ml shall be analyzed as follows:

- Assemble a cleaned filtration apparatus.
- Using clean forceps with nonserrated tips, place a filter membrane (47-mm diameter with 0.45-micron pores) in position in the filter holder. The filter membrane must be compatible with the test solvent. Prior to insertion, the filter membrane may be rinsed with filtered test solvent to remove any adherent contamination.

3.10.2. Nonvolatile Residue (NVR) Analysis

The NVR analysis shall be determined using the gravimetric method described below.

3.10.2.1. Test Procedure - Piping

The solvent-flush test procedure shall be as follows:

- Ascertain the total volume of test solvent necessary to flush the cleaned item or items.
- Flush all critical surfaces uniformly with the test solvent. Tubing, piping, and hoses shall to be flushed at 4 ft/s (minimum).

- Catch 1000 ml of the test solvent in a precision cleaned glass container. For each 1000 square feet in the system after the first thousand square feet, collect an additional 1000-ml sample.
- Immediately upon the completion of the above step, dry the tested items using dry nitrogen gas.

3.10.2.2. Test Procedure - Components

The solvent-flush test procedure shall be as follows:

- Ascertain the total volume of test solvent necessary to flush the cleaned item or items.
- Flush all critical surfaces uniformly with the test solvent. Where flushing does not reach all interior surfaces, the test solvent shall be introduced and the item manually shaken.
- Catch the test solvent in a precision cleaned glass container.
- Immediately upon the completion of the above step, dry the tested items using dry nitrogen gas.

3.11. GRAVIMETRIC METHOD

The NVR shall be determined by weighing the residue left after evaporation of the solvent flush fluid. The NVR shall be reported as:

- Parts per million (ppm) by weight or
- Milligrams per square foot (mg/ft^2)

as calculated by the method shown below. Milligrams per square foot is the preferred method to determine the NVR. In the following description, "solvent" means clean trichlorotrifluoroethane, and "sample" means the solvent flush fluid that has been used to flush the system being cleaned.

3.11.1. Equipment Required

The following equipment shall be required:

- Aluminum foil dish with smooth sides and a capacity of about 65 ml.
- Graduated cylinder, 1000-ml capacity with 10-ml divisions.
- Beaker, 660 ml capacity with 50 ml graduations.
- Watch glass to cover 600-ml beaker.
- Oven, capable of temperature setting at 100 °F.
- Desiccator with indicating type silica gel.
- Balance, capable of weighing to 0.0001 gm (0.1 mg).

3.11.2. Procedure

A sample shall be obtained as follows:

PPM method: As outlined in sections 3.10.2.1 or 3.10.2.2.

Milligrams per square foot method: A known surface area (typically

0.1 m² or 1 ft²) shall be rinsed with enough solvent to obtain a reasonably sized sample (e.g., 500 ml of solvent). The sample shall be collected using section 3.10.2 as a guide.

Once a sample has been obtained, the following procedures shall be observed:

- All glassware and the aluminum weighing dish shall be cleaned with clean solvent before use.
- The aluminum dish shall be dried in the oven at 100 °F for one hour and cooled in the desiccator before weighing. The dish shall be weighed, and its weight recorded to 0.0001 gram. Use formula shown in this section.
- The sample shall be measured in the graduated cylinder. About 500 ml shall be transferred to the beaker, covered with the watch glass, and evaporated at a gentle boil on the hot plate. Add additional sample periodically as the material in the beaker boils away. This process shall be conducted in an appropriately vented location, such as a fume hood.
- When the sample volume has evaporated to less than 100 ml, wash the sides of the beaker a few times with solvent.
- When the sample volume has evaporated to less than 40 ml, pour the beaker contents into the pre-weighed aluminum dish. Rinse the beaker with a small volume of solvent to transfer all residue into the aluminum dish.
- Evaporate the contents of the aluminum dish to dryness on a low temperature setting of the hot plate. The sample shall not boil actively. Remove the dish from the hot plate as soon as dryness is reached and place in the 100 °F oven for one hour. Cool the dish in the desiccator, weigh to 0.0001 gram, and record its weight.

3.11.3. Calculation

NVR is calculated as follows:

PPM method:

(Weight of dish+residue)* - (weight of dish)** = (weight of residue, grams)

$$\text{NVR in ppm} = \frac{(\text{weight of residue, gram}) \times (1000 \text{ mg/g})}{\left(\frac{1.565 \text{ kg}}{1000 \text{ ml}} \right) \times (\text{volume of sample, ml})}$$

(*Last step, Section 3.11.2; **second step, Section 3.11.2)

Milligrams per square foot method:

(Weight of dish+residue)* - (weight of dish)** = (weight of residue, grams)

$$\text{NVR in mg/ft}^2 = \frac{(\text{weight of residue, gram}) \times (1000 \text{ mg/g})}{\text{area of test surface (ft}^2\text{)}}$$

(*Last step, Section 3.11.2; **second step, Section 3.11.2)

For the milligrams per square foot method, NVR shall not be more than 1 mg/ft² for the tested item(s) to be accepted as clean. A ppm of less than 10 is required for the tested item(s) to be accepted as clean.

Place the aluminum foil dish with residue in a small plastic bag with a sealable strip and attach it to the report.

Where specifications call for both particle analysis and NVR analysis, the test can be combined to conserve test solvent. The particle filtrate can be analyzed via the gravimetric method for NVR.

3.12. ACCEPTANCE INSPECTION OF PACKING MATERIALS

All plastic films used for packaging shall comply with the requirements of Table 3.1, below. Acceptance inspection for conformance to the requirements of Table 3.1 shall be in accordance with Section 3.12.2. Cleanliness level of inner wrap shall be at least equal to exposed cleaned surfaces of the item. Unless otherwise specified, outer wrap shall be visibly clean in accordance with Section 3.12.3.

Table 3.1, Packaging Films.

Film	Thickness Range (mils)	Use
Polyethylene in accordance with L-P-378, Type II	5.4 to 6.6	Overwrap
Aclar 22A or equivalent fluorohalocarbon in accordance with AMS 3649	1.7 to 2.3	Packaging, suitable for liquid and gaseous oxygen

Selection of a specific film shall be dictated by compatibility with the specified service medium. All parts which come in contact with liquid or gaseous oxygen service shall be protected with an inner bag or layer(s) of a fluorohalocarbon film conforming to Aerospace Material Specification (AMS) 3649 such as Aclar 22A.

Systems, subsystems, and components shall be protected with an inner bag or layer(s) of a polyamide film or a fluorohalocarbon film. Polyamide films have a higher resistance to sloughing particles, while fluorohalocarbon films provide a better barrier to moisture vapor and gas permeability.

All clean film (including bags, sheeting, tubing, and roll stock) that is not used immediately after cleaning, shall be overwrapped and sealed in an inner bag

made from clean film of the same type. All film procured clean shall be overwrapped with a second bag of clean, 6 mil, antistatic polyethylene prior to packaging for shipment. Roll stock shall be wound on clean cores made from nondusting plastic or metal.

3.12.1. Environmental Control

All quality assurance operations shall be accomplished within a clean room conforming to FED-STD-209 that is consistent with or cleaner than the packaging material being inspected. Care shall be taken not to contaminate the packaging materials.

3.12.2. Sampling

Packaging materials shall be examined and tested to determine compliance with the cleanliness requirements of Section 3.12. All the plastic film of one type, one size, and one configuration such as tubing, flat roll stock, sheet, and fabricated bags offered by one manufacturer at one time shall be considered one lot.

3.12.3. Visual Inspection

No evidence of oil, solvents, paints, grease, dirt, ink, metal chips, or other foreign matter shall be permitted on either the external surface or the internal surfaces of packaging materials when inspection is made with the unaided eye.

3.12.4. Thickness of Packing Film

The thickness of plastic films used for packaging shall conform to the limits specified in Table/Thickness. Measurements shall be made with a micrometer caliper having a flat anvil and capable of being read to the nearest 0.0001 inch.

3.12.5. Verification of Cleanliness Level

All plastic films of one lot shall have the cleanliness level verified prior to use. When a lot contains a large number of plastic films, test one bag in every hundred.

3.12.6. Minimum Critical Surface Area for Test

The minimum interior critical surface area for verification of cleanliness level shall be 1 ft². Sampling shall be according to Section 3.12.2 except that additional sample material from the offered lot shall be used when necessary to make 1 ft².

3.12.7. Sample Preparation

Fabricated bags shall be sealed across the open end. Tubular packaging material shall be fabricated into a bag by cutting off a length conforming to the requirements of the above section and sealing both ends. Flat roll stock and sheet shall be fabricated into a bag by cutting out a section conforming to the requirements of Section 2.9.3.1, folding the section, and sealing the section as necessary. The cutting technique shall also be in accordance with Section 2.9.3.1. The sealing technique shall be in accordance with Section 2.9.3.2. All items shall be handled in such a manner as to minimize exposure of the interior critical surfaces to

airborne particles. One corner of the completely sealed test bag shall be cut off so that an opening of a maximum of 0.75 inch in length is created.

3.12.8. Rinsing Procedures

Trichlorotrifluoroethane that conforms to the cleanliness level of Section 3.9.2 shall be used as the test solvent in the ratio of 100 ml of solvent per square foot of critical surface area. The following rinsing procedure shall be used:

- Introduce test solvent into the sealed bag through the previously cut opening.
- Close the bag by folding over the cut corner.
- Gently agitate the test solvent within the bag for a minimum of 15 seconds, wetting all surfaces.
- Pour the used test solvent into a precision-cleaned beaker, taking care to exclude airborne contamination.
- Analyze the test solvent for particulate population and NVR in conformance with Section 3.8.2 of this procedure.

Chapter 4**4. PREPARATION FOR DELIVERY****4.1. PRESERVATION AND PACKAGING**

Preservation and packaging of cleaned items shall be in accordance with Chapter 2.

4.2. PACKING**4.2.1. Onsite Transportation of Small Items**

Small items that have been protected in accordance with Section 2.9 shall be packed as required. Cushioning material shall be used to immobilize the item and prevent damage to the packaging. When a number of small, individually packaged items are packed, cushioning material shall be used to separate the package and to immobilize the packages. Cushioning materials such as excelsior, shredded newspaper, and similar materials that generate large numbers of particles and fibers shall not be used.

4.2.2. Offsite Shipment

Packing of cleaned items for offsite shipment shall be in accordance with level A or B of MIL-STD-794 or MIL-E-17555 as applicable to the type of item being packed. Level A packing shall be used when storage conditions are indeterminate and may involve outdoor storage. Level B packing shall be used when handling under cover and warehouse storage is possible.

4.3. MARKING FOR SHIPMENT

Shipping containers shall be marked in accordance with MIL-STD-129 and shall include special marking in addition to that specified in MIL-STD-129 to the effect that cleaned items are contained therein.

Chapter 5

5. RESPONSIBILITY

5.1. PERSONNEL

The appropriate Facility Safety Head and Facility Coordinator are jointly responsible for maintaining the integrity of an oxygen clean system after its acceptance.

5.2. INTERPRETATIONS

Questions concerning content, interpretation of this procedure, or unusual situations not covered in this text shall be referred to the Process Systems Branch for final resolution.

Appendix A**A. ABBREVIATIONS AND ACRONYMS**

AMS	Aerospace Material Specification
ASTM	American Society for Testing and Materials
C	degrees Celsius
cd	candela
F	degrees Fahrenheit
ft/s	feet per second
g	grams
h	hour
HEPA	high-efficiency particulate air
LaRC	Langley Research Center
LOX	liquid oxygen
m	meter
max	maximum
mg	milligram
ml	milliliter
mm	millimeter
NASA	National Aeronautics and Space Administration
no.	number
NVR	nonvolatile residue
ppm	part per million
psig	pounds per square inch
qty	quantity
s	second
SAE	Society of Automotive Engineers

Appendix B**B. DEFINITIONS**

Accuracy	Accuracy is how close the measured value is to the "true" value.
Assembly	An assembly is two or more parts having a common mounting and being capable of performing a definite function. For example, filter element, housing, and O-ring become part of a filter assembly.
Blank	A blank is the result for an analytical sample of the test fluid prior to use in performing a cleanliness verification test.
Component	A component is an article that is normally a part of a subassembly or assembly and is a self-contained element within a complete operating system.
Component Cleaning	Any cleaning activity taking place in a centralized facility dedicated to cleaning components, assemblies and subassemblies. The cleaning process includes the following tasks: check in, disassembly (if necessary), preclean, precision clean, verification, reassembly (if required), and functional testing.
Condensable Hydrocarbon	A condensable hydrocarbon is a hydrocarbon capable of going from a gaseous to a liquid or solid state at ambient temperature and prevailing pressure.
Critical Surface	Any surface of an item that contacts the critical service medium (liquid oxygen, pneumatic gases, etc.) is considered a critical surface. A critical surface is subject to the cleaning procedures and cleanliness requirements of this specification
Dewar	A dewar is a double-walled vessel with the annular space between the walls evacuated to provide insulation.
Dewpoint	Dewpoint is the temperature at which condensation of water vapor takes place at prevailing pressure (usually atmospheric pressure).
Fiber	A fiber is a nonmetallic, flexible structure having a length-to-width ratio of 10 to 1 or greater.
Fluid	For the purpose of this specification, a fluid is defined as a gas or liquid.

Generally Clean (GC)	Generally clean (GC) is freedom from manufacturing residue, dirt, oil, grease, processing debris, or other extraneous contamination. This level can be achieved by washing, wiping, blowing, vacuuming, brushing, or rinsing. This level shall not be designated for hardware that is sensitive to contamination.
Hydrocarbon	A hydrocarbon is an organic compound consisting exclusively of the elements of carbon and hydrogen.
Hypergolic Propellant	A hypergolic propellant is any fuel/catalyst (monopropellant) or fuel/oxidizer (bipropellant) combination that spontaneously ignites and is used in propelling a rocket.
Micrometer	One micrometer is equivalent to 0.001 millimeter, 0.000001 meter, 0.0000394 inch, or 0.0394 mil (one mil is equal to 0.001 inch).
Nonvolatile Residue	Nonvolatile residue is soluble or suspended material and insolubly particulate matter remaining after temperature controlled evaporation of a filtered volatile liquid.
Oxidizer	Oxidizers are commodities, such as liquid oxygen and nitrogen tetroxide, which when combined with fuels (liquid hydrogen and hydrazine respectively) constitute the propellants for rocket engines.
Part	A part is one piece of two or more pieces joined together in such a way that it is not normally disassembled without destruction of the designed use. Fittings, O-rings, and poppets are normally considered parts of a valve.
Particle	A particle is a unit of matter with observable length, width, and thickness and is usually measured by its largest dimension in micrometers.
Parts per Million (ppm) by Weight	An absolute weight relationship expressed on an equivalent basis in any weight unit. The user may employ a weight unit that is convenient. One ppm may be 1 gram per million grams, 1 pound per million pounds, etc..
Passivation	Passivation is the process by which a corrosive-resistant layer is bonded to a metal surface by submerging the surface in an acid solution.

pH	A value taken to represent the acidity or alkalinity of an aqueous solution. It is defined as the logarithm of the reciprocal of the hydrogen ion concentration of a solution. The pH is measured over the nominal range of 0 to 14. A pH reading below 7 is acidic, pH 7 is neutral, and pH above 7 is alkaline.
Pickling	Pickling is the chemical or electrochemical process by which surface oxides are removed from metals.
Precision Cleaning	Precision cleaning is a cleaning process used to achieve cleanliness levels more stringent than level VC.
Repeatability	Repeatability is reproducibility to acceptable level of precision.
Rough Cleaning	Rough cleaning is the cleaning process normally used to achieve cleanliness level VC.
Silting	Silting is an accumulation of particles (approximately 2 to 20 gm) of sufficient quantity to cause a haze or obscuring of any portion of a grid line or any portion of the grid of a filter membrane when viewed visually or under 40--power maximum magnification.
Subsystem	A subsystem is two or more assemblies joined together to perform a definite function. A subsystem should be capable of independent operation when interconnected into a system.
System	A system is a series of subsystems joined together to perform a definite function.
Test Fluid	Test fluid is either a liquid solvent or an aqueous solution that is utilized to determine fluid system wetted-surface cleanliness level.
Validate/Validation	Validate/validation is the process or method of proving that an item subsystem or system does meet the specified requirements (for example, to validate the integrity of the system).
Verify/Verification	Verify/verification is the process or method to establish the truth, accuracy, or reality of the cleanliness level of a cleaned item (for example, to verify the cleanliness level of a system).

Visually Clean (VC)	Visually clean is the absence of all particulate and nonparticulate matter visible to the normal unaided (except corrected vision) eye. Particulate is identified as matter of miniature size with observable length, width, and thickness. Nonparticulate is a film matter without definite dimension. This level, with the exception of the orbiter payload (cargo) bay, payload canister, and payloads, requires precision cleaning methods but no particle count.
Visually Clean Plus Ultraviolet (UV)	UV is visually clean (VC) and inspected with the aid of an ultraviolet light (black light) of 3200 to 3800 angstroms wavelength (3.2×10^{-7} to 3.8×10^{-7} meters). This level requires precision cleaning methods but no particle count. Fluorescents indicate possible hydrocarbon contamination. If recleaning fails to remove fluorescent indications, an investigation should be made to determine if the item material is naturally fluorescent.
Volatile Hydrocarbon	A volatile hydrocarbon is a hydrocarbon capable of going from liquid or solid to a gaseous state at ambient temperature and prevailing pressure.

Appendix C**C. REFERENCE DOCUMENTS****GOVERNMENT DOCUMENTS****Federal Specifications:**

L-P-378	Plastic Sheet and Strip, Thin Gauge, Polyolefin
O-E-00760	Ethyl Alcohol (Ethanol); Denatured Alcohol; Proprietary Solvents and Special Industrial Solvents
PPP-T-66	Tape: Pressure-Sensitive Adhesive, Vinyl Plastic Film, Type I, Class B
TT-I-735	Isopropyl Alcohol, Grade A

Military Specifications:

MIL-E-17555	Electronic And Electrical Equipment, Accessories, And Associated Repair Parts; Packaging And Packing Of
MIL-C-81302	Cleaning Compound, Solvent, Trichlorotrifluoroethane
MIL-P-27401	Propellant Pressurizing Agent, Nitrogen, Type I, Grade A

Federal Standard:

FED-STD-209	Clean Room and Work Station Requirements, Controlled Environment
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Military Standards:

MIL-STD-129	Marking for Shipping and Storage
MIL-STD-794	Parts and Equipment, Procedures for Packaging and Packing of
MIL-STD-889	Dissimilar Metals

NASA Standards:

LPR 1710.40	Safety Regulations Covering Pressurized Systems
79K09560	Material Selection List for Liquid Oxygen Service
79K09561	Material Selection List for Gaseous Oxygen and Air Service
JSC-SPEC-C-20C	Water, High Purity Specification for

NONGOVERNMENT DOCUMENTS

***American Society for Testing and Materials (ASTM):**

ASTM F 312	Microscopical Sizing and Counting Particles from Aerospace Fluids on Membrane Filters
ASTM D 1414-72	Standard Method of Testing - Rubber O-Rings
ASTM D 471-79	Rubber Properties - Effect of Liquids Test Methods

****Society of Automotive Engineers (SAE) Aerospace Material Specifications (AMS):**

AMS 3649	Polytrifluorochloroethylene Film (PCTFE), Unplasticized
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